Encyclopedia of
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EDITED BY
PAUL DEMENY
GEOFFREY MCNICOLL

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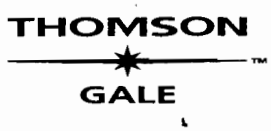

Encyclopedia of Population

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from injury and poisoning increases fairly rapidly. This is mainly due to rising mortality from accidents such as falls and the inhalation or ingestion of harmful substances, reflecting the weakening of the musculoskeletal system and diminishing effectiveness of neural control of the body.

See also: *Aging and Longevity, Biology of; Causes of Death; Epidemiological Transition; Gompertz, Benjamin; Life Tables.*

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SHIRO HORIUCHI

MORTALITY, INFANT AND CHILD

See *Infant and Child Mortality*

MORTALITY DECLINE

One of the greatest human achievements has been the decline in mortality that has occurred during the modern era. This article describes major trends in human mortality and longevity, especially during the nineteenth and twentieth centuries. The data are derived mostly from detailed mortality statistics collected by national governments. Prior to 1950 reliable information of this kind was collected by only a small number of countries, mostly in Europe, North America, and East Asia. As leaders in industrialization and other forms of social change during this period, these areas have also led the mortality decline and offer valuable statistical documentation of historical trends.

Substantial mortality decline in other parts of the world is a more recent phenomenon, sharply accelerating after 1950, although demographic data to document these trends are deficient in many cases. Similar changes in society and technology underlie mortality declines in all parts of the world, although there are also some regional patterns and exceptional trends.

TABLE 1

Life Expectancy and Infant Mortality throughout Human History

	Life expectancy at birth (in years)	Infant mortality rate (per 1000 live births)
Prehistoric Era	20–35	200–300
Sweden, 1750s	37	210
India, 1880s	27	230
United States, 1900	48	133
France, 1950	66	52
Japan, 1999	81	3

SOURCE: Wilmoth (2002, updated); Bhat (1989).

Sources of Information

It is not known with accuracy how long individuals lived before 1750. Around that time the first national population data were collected for Sweden and Finland. After 1750 and even now in the twenty-first century there is extensive and highly reliable mortality information for only a subset of national populations. For many less developed countries modern mortality estimates are based on sample surveys or other study designs that do not include the entire population and, especially for adults, are not highly reliable.

For the period from around 1500 to 1750 there are several examples of reliable mortality data referring to municipal populations, members of the nobility, and other groups that cannot be considered representative of the total population. For the Middle Ages and earlier periods mortality levels have been estimated through the use of data gleaned from tombstone inscriptions, genealogical records, and skeletal remains. Such estimates are prone to various forms of error but provide a useful description of the general contours of human mortality before the great mortality decline of the modern era.

Mortality data often include information on the cause of death, although this concept is difficult to define and measure consistently. Data on the cause of death always must be analyzed with great caution: Although some trends are irrefutable such as the historical decline of infectious disease, others appear to be influenced by changes in diagnostic procedures and reporting practices (e.g., cancer trends, especially among older persons).

Historical Trends

Historical changes may be described along various dimensions. The following sections examine the rise of life expectancy, changes in the age pattern of human mortality, and trends in extreme longevity.

Life expectancy. Most scholars agree that life expectancy at birth (or $\mathring{e}_0$, in the notation of demographers and actuaries) was probably in the 20s among early human populations (Table 1). Some less fortunate populations may have had life expectancies below 20 years. If early levels of life expectancy at birth were around 20–30 years compared to 75–80 years in the early twenty-first century in some countries, one may conclude that there has been roughly a tripling over the course of human history in the average life span that can be attained by large populations. Much of this increase has been due to the near elimination of infant and childhood deaths. In early human populations the available evidence suggests that around a quarter of all babies died in the first year of life. In the early twenty-first century in the most advanced countries, less than half a percent of infants meet a similar fate.

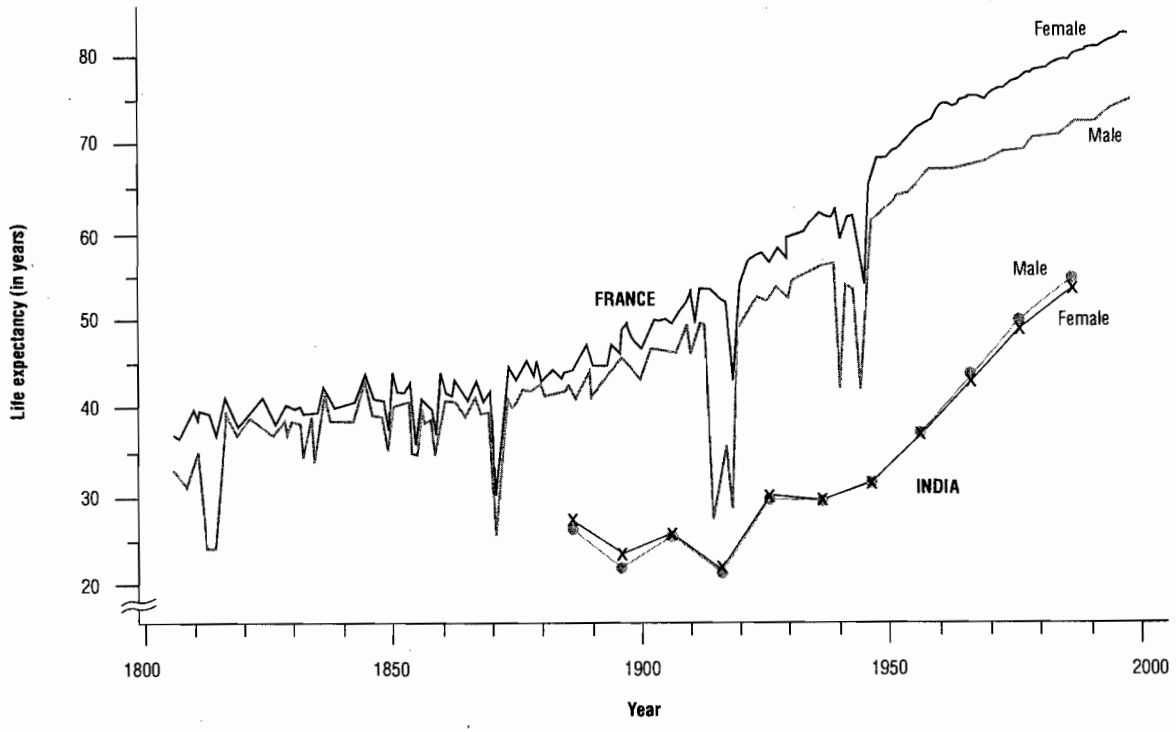
Most of the increase in human longevity is recent. By 1900 the average newborn in Australia and New Zealand could be expected to live about 55 or 57 years, respectively, based on mortality levels in those countries, which were the lowest in the world at that time. In 2000 the world's healthiest nation, Japan, had a life expectancy at birth of around 81 years. Thus, in the leading countries almost half the historical increase in human life expectancy occurred during the twentieth century.

The rise in life expectancy at birth probably began before the industrial era in some parts of Europe and North America. By the 1750s, when data for national populations first became available, life expectancy in some areas of northern Europe was already in the high 30s. Over the next century or more the increase in life expectancy was slow and irregular. After about 1870, this increase became stable and more rapid, especially during the first half of the twentieth century. Since 1950 the rise in life expectancy has slowed somewhat in those areas that led the longevity revolution, such as Europe and North America.

Figure 1 shows trends in life expectancy at birth for males and females in France since 1806. This graph summarizes key aspects of French mortality history over the nineteenth and twentieth centuries. First, life expectancy increased from the high 30s at the beginning of the nineteenth century to the 70s or 80s at the end of the twentieth. Second, the im-

FIGURE 1

Life Expectancy at Birth, by Sex, in France, 1806–1997, and India, 1881–1891 to 1981–1991



SOURCE: Vallin and Meslé (2000); Bhat (1989, 1998, 2002).

pact of various wars was different for the sexes. The Napoleonic wars and World War I were fought mostly at the front and thus affected male life expectancy strongly, but their effect was minor on females in most parts of the country. On the other hand, the Franco-Prussian war and World War II involved widespread occupations of the French territory by enemy forces and thus affected men and women in a similar fashion. Third, a large male–female gap in life expectancy emerged even during peacetime, increasing from a difference of less than two years at the beginning of the period shown to around eight years at the end.

The mortality decline of the modern era began in countries that were leaders in the process of industrialization, but it has spread across the entire world. Alongside the trend for France mentioned earlier, Figure 1 also shows the rise in life expectancy at birth for India from the 1880s until the 1980s. As in most of the poorer regions of the world, the majority of this increase has occurred since around 1940. Fragmentary evidence suggests that life expectancy in the period 1935–1939 was around 30 years in Africa and Asia and 40 years in Latin America. Around 2000, estimates for these regions were much higher at 53, 67, and 71 years, respectively, as summarized in Table 2.

Many factors have contributed to the rise of life expectancy all around the world. Prior to the last decades of the nineteenth century most of the reduction of mortality rates in the early industrializing countries was likely the result of improved living conditions (e.g., better nutrition, shelter, and clothing) made possible by the increased wealth brought about by industrialization. In addition, confirmation of the germ theory of disease in 1882—as a result of Koch's rigorous identification of the bacillus that cause tuberculosis—led to a flourishing of public health measures (e.g., anti-malarial programs, immunization campaigns, and other government health initiatives) and associated improvements in personal health practices. Such developments were

TABLE 2

Life Expectancy at Birth for Major World Regions and Selected Countries, around 2000

Region/Country	Life expectancy at birth (in years)	Region/Country	Life expectancy at birth (in years)
World	67	Europe	74
More developed	76	France	79
Less developed	65	Germany	78
Africa	53	Italy	80
Congo, Dem. Rep. of	49	Poland	74
Egypt	66	Russia	65
Ethiopia	52	Ukraine	68
Nigeria	52	United Kingdom	78
South Africa	51	Latin America & Caribbean	71
Tunisia	72	Argentina	74
Zimbabwe	38	Brazil	69
Asia	67	Chile	77
Bangladesh	59	Colombia	71
China	71	Cuba	76
India	63	Guatemala	66
Indonesia	68	Haiti	49
Iran	69	Mexico	75
Japan	81	North America	77
Laos	54	Canada	79
Pakistan	63	United States	77
Philippines	68	Oceania	75
Turkey	69	Australia	80
Vietnam	68	Papua-New Guinea	57

Note: Following the U.N. classification, "more developed" regions include all of Europe, North America, Japan, Australia, and New Zealand. All other areas are classified as "less developed."

SOURCE: Population Reference Bureau (2002).

probably the major factor in mortality reduction, in both rich and poor countries, from the late-nineteenth century until the 1960s. As discussed below, the main contributions of therapeutic medicine to the historical mortality decline arrived relatively late in this process: antibacterial drugs from the 1930s and 1940s onward, and improved management of cardiovascular disease beginning around 1970.

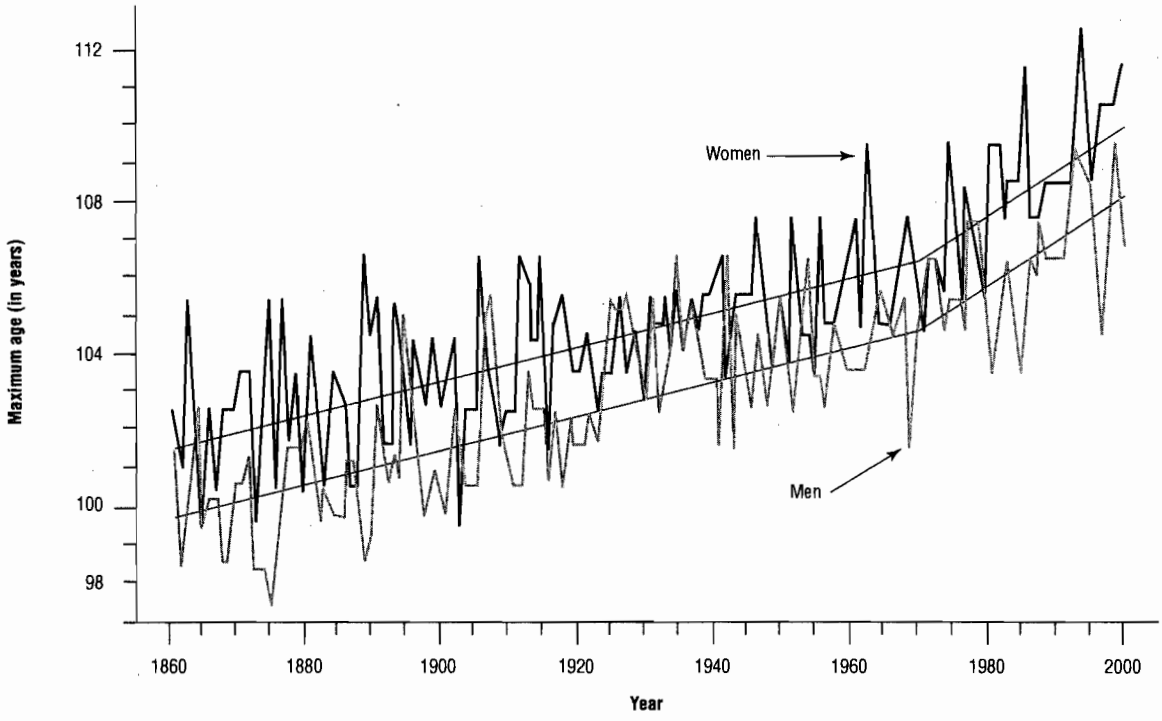
Although the general trend toward lower mortality and higher life expectancy has become worldwide, there are a few notable exceptions. During the 1990s the major exception was a stagnation and even reversal of earlier progress in parts of Africa because of the AIDS epidemic and in parts of the former Soviet Bloc (especially Russia) resulting from social disruptions and instability.

Age pattern of human mortality. The age pattern of human mortality can be characterized in various ways. Age-specific death rates depict the changing risks of mortality over the life course. During the historical mortality decline, death rates typically have fallen much more rapidly at younger than at older ages. A complete set of age-specific death rates implies a particular distribution of deaths by age for a cohort of individuals. Because mortality decline has been more rapid at younger ages, the distribution of ages at death has become more concentrated at older ages. Thus, not only is life longer on average, but also the age range in which most deaths occur has been reduced substantially.

One measure of variability in the timing of death is the interquartile range of ages at death, thus the age span of the middle 50 percent of deaths over the life course of a cohort. The calculation is most simply done for the synthetic cohort of a period life table. During the late-eighteenth century in Sweden, the life-table interquartile range was around 60 to 65 years, since more than one quarter of infants died before age 5, while another quarter survived to age 65 or older. The distribution of age at death was compressed over the next two centuries. In the 1950s the life-table interquartile range in the industrialized countries was around 15 to 20 years. Since 1960 there has been little further reduction in the variability of age at death in the developed world, even

FIGURE 2

Maximum Reported Age at Death, by Sex, in Sweden, 1861–2000



SOURCE: Wilmoth et al. (2000, updated).

though the average age at death (as reflected in life expectancy at birth) has continued to increase.

Extreme longevity. It is difficult to study trends in extreme longevity because of frequent errors in the age at death reported for very old individuals. For this specialized purpose the longest available series of reliable data begins in the 1860s for Sweden. Figure 2 shows the trend in the maximum age at death for men and women over the period 1861–2000. The trend is clearly upward, especially from about 1970. The maximum age rises by 0.44 years (of age) per decade prior to that date and by 1.1 years per decade since then. More than two-thirds of this increase can be attributed to reductions in death rates above age 70, with the rest being due to the fact that more people reach old age (and thus have a chance to die at a very old age) as a result of mortality decline at younger ages and a modest increase in the size of birth cohorts.

These Swedish data provide the best available evidence for the gradual extension of the maximum human life span that has occurred over this time period. Similar trends are evident for other countries as well, although problems of age misreporting complicate the task of interpretation.

Components and Causes of Mortality Decline

The mortality decline of the last two centuries has many components and causes. Two major components of the trend are discussed below: (1) the decline of infectious disease, known as the epidemiologic transition, and (2) the decline of old-age mortality in more recent years. In both cases the causes of the change are complex and can be linked to socioeconomic conditions, public health measures, individual behaviors, and medical interventions.

Epidemiologic transition. The epidemiologic transition is the most important historical change that has affected the level and pattern of human mortality. The transition refers to the decline of

acute, infectious diseases and the rise of chronic, degenerative conditions. This shift does not necessarily imply that degenerative diseases became more common for individuals of a given age. It merely means that infectious diseases nearly disappeared, and so something else had to take their place as the major cause of death.

Increasingly, people survived infancy and childhood without succumbing to measles, tetanus, whooping cough, diphtheria, and other infectious causes of juvenile mortality. Once people pass these critical early years, survival to advanced ages is much more likely, and at older ages various degenerative diseases present mortality risks even when infections are well controlled.

The cause of the historical decline of infection-related mortality has been a topic of much discussion. It has become widely acknowledged that most of this decline occurred before the availability of effective medical treatments: In the wealthy countries that industrialized early a substantial reduction had occurred by the 1930s and 1940s, the period when effective antibacterial drugs (sulfanomides and antibiotics) were introduced. Instead, the decline can be attributed mostly to the general improvement in living standards that accompanied industrialization (food, housing, clothing, etc.) and to public health measures that helped control the spread of germs (sanitation, clean drinking water, education about hygiene, quarantine, etc.).

In the countries of Europe and North America this process of epidemiologic transition began during the nineteenth century and was completed mostly before 1960. A similar process began later in the economically less advantaged regions of the world. Mortality decline began in the early-twentieth century in some parts of Latin America and East Asia. In sub-Saharan Africa, in contrast, there is little evidence of mortality reduction before the late 1940s. Even in the early twenty-first century residents of poor countries bear an undue burden of mortality linked to infection. In these cases the successes brought about by organized public health campaigns have not been matched by comparable improvements in the general standard of living.

Mortality decline among the elderly. By around 1960 mortality resulting from infectious diseases had been reduced to very low levels in industrialized countries, and it appeared to many observers that a further extension of the human life span was unlikely. Few people anticipated the coming reduction in old-age mortality that would prolong the historical trend toward longer life into the twenty-first century. Before the late 1960s death rates at older ages seemed to have declined slowly, if at all, and rates of mortality decline were much higher at younger ages than at older ages.

In wealthy nations of the late twentieth century, the most significant change affecting life expectancy was mortality decline among the elderly. The decade of the 1960s marked a turning point from an earlier era of longevity increase caused primarily by the decline of acute, infectious diseases among children and young adults to a more recent era characterized by the decline of chronic, degenerative diseases among the elderly.

Mortality decline at older ages in the last decades of the twentieth century was linked mainly to the reduction of deaths resulting from cardiovascular disease (CVD)—essentially, heart disease and stroke. For the United States it is estimated that 73 percent of the decline in the total death rate from 1950 to 1996 was due to a reduction in CVD mortality. Although the exact cause of this decline is open to debate, several factors have been proposed: (1) a decline in cigarette smoking among adults; (2) a decrease in mean blood pressure levels; (3) changes in diet, especially a reduction in the consumption of saturated fat and cholesterol; and (4) improvements in medical care, including better diagnosis and treatment of heart disease and stroke, the development of effective medications for hypertension and hypercholesterolemia, and an increase in coronary-care units and emergency medical services for heart disease and stroke.

A rapid decline in old-age mortality beginning in the late 1960s has been observed for many industrialized nations. Given the precipitous onset of this decline, which occurred simultaneously across a broad age range, it is plausible that improvements in medical therapy were responsible at least for the initiation of the new trend. Landmark investigations such as the Framingham Heart Study that began in the late 1940s provided significant breakthroughs in the scientific understanding of cardiovascular disease during the 1960s, leading to more effective medical prevention and management. Since modifications in diet and lifestyle should have led to a more gradual pattern of mortality change, it seems unlikely that such factors have been the main cause of the

TABLE 3

Summary of Major Trends in Human Longevity in Industrialized Countries

Indicator	Before 1960	After 1970
Average life span (life expectancy at birth)	Increasing rapidly because averted deaths are among younger people. Very rapid reduction in infant/child mortality linked mostly to effective control of infectious diseases.	Increasing moderately because averted deaths are among older people. Accelerated reduction in old-age mortality linked mostly to better management of cardiovascular disease.
Maximum life span (observed and verified maximum age at death)	Increasing slowly due mostly to gradual reductions in death rates at older ages.	Increasing moderately due almost entirely to accelerated reduction in death rates at older ages.
Variability of life span (standard deviation, interquartile range, etc.)	Decreasing rapidly due to reductions in mortality at younger ages.	Stable, because death rates at older ages are decreasing as rapidly as at younger ages.

SOURCE: Author.

recent decline in old-age mortality. Nevertheless, it is possible that behavioral changes or other factors have reinforced a trend that was set in motion initially by improvements in medical therapy.

After CVD, cancer is the most important cause of death in low-mortality countries of the twenty-first century. In most of these countries cancer mortality began to decline in the late 1980s, although the change has been less rapid and more varied than the trend in CVD mortality. Cancer occurs in many different forms, and trends vary greatly by the site of the primary tumor. For example, lung cancer has become more common over time as a result of increased cigarette smoking, whereas the incidence of stomach cancer has declined. Among women mortality from cervical cancer has fallen markedly as a result of successful medical intervention (screening and early treatment), whereas breast cancer has been on the rise apparently as a result of a number of interrelated factors, such as lower and later fertility and changes in diet and lifestyle.

Summary of Major Trends in Low-Mortality Countries

A summary of major trends in human longevity in industrialized countries is presented in Table 3. Amid the remarkable detail available in historical mortality statistics two major epochs are discernible: before 1960, and after 1970. The driving force in the earlier period was a rapid decline in mortality from infectious diseases, which had an impact across the age range but a much larger effect at younger ages. The sharp reduction in infant and child mortality led to a rapid increase in average life span and a marked reduction in the variability of age at death. It did not, however, have a major impact on the maximum life span, which rose very slowly as a result of the more gradual improvement in death rates at older ages.

From the mid-1950s to the late 1960s mortality trends in industrialized countries seemed to stabilize. Then, starting from about 1970, death rates at older ages entered a period of unprecedented decline. Compared with the earlier era of rapid reductions in infant and child mortality, these changes yielded a slower increase in life expectancy at birth. However, the rise in the maximum life span accelerated, driven by a more rapid decline in death rates at older ages. The variability of the life span tended to stabilize during this period, as the entire distribution of ages at death—now concentrated at older ages—moved upward in a parallel fashion. The difference between these two eras is illustrated in Table 4 for Sweden.

Prospects for the Future

The rapid rise in life expectancy before 1950 and its subsequent deceleration are linked to trends in mortality at young ages. By around 1950 infant mortality in wealthy countries was in the range of 20 to 30 per 1,000 births, compared with perhaps 200 to 300 per 1,000 births historically. Since that time infant mortality has continued to decline, and early in the twenty-first century it is below 4 per 1,000 births in the healthiest parts of the world. As babies were saved from infectious disease, their chances of survival to old age improved considerably. Once mortality at young ages was reduced substantially, improvements in life expectancy caused by the

reduction of mortality in this age range had to slow down, and further gains had to come mostly from mortality reductions at older ages.

The rise of life expectancy in the leading industrial countries was slower during the second half of the twentieth century than during the first half because it depended on the reduction of death rates at older ages rather than in infancy and childhood. Put simply, saving an infant or child from infectious disease, who then lives to age 70, contributes much more to the average life span than does saving an adult of 70 years from heart disease, who may then live another 10 years. Thus, the deceleration in the historical rise of life expectancy is a product of the J-shaped age pattern of human mortality: relatively high in infancy and childhood, low through adolescence and early adulthood, and rising steeply after age 30. Gains in life expectancy at birth that result from reducing mortality among the young are large, whereas gains resulting from a reduction in old-age mortality are necessarily much smaller.

It is a common mistake to assert that deceleration in the rise of life expectancy at birth, $\mathring{e}_0$, reflects a slowdown in progress against mortality. In fact, the reduction of death rates changed its character in the late-twentieth century, but it did not slow down. At older ages the decline of mortality has accelerated since around 1970. As long as the decline of old-age mortality continues, life expectancy will continue to increase, driven now by the extension of life at older ages rather than by saving juveniles from premature death.

The historical rise in human longevity is the result of a complex set of changes that began several centuries ago. Before the 1930s most of this decline was due to factors other than medical therapy and is generally attributed to improvements in living conditions and public health. With the advent of antibacterial drugs in the 1930s and 1940s, medical treatment began to play an important role in these changes. The role of medicine expanded in the late-twentieth century because of interventions in cardiovascular disease and cancer that have contributed to the rapid decline of old-age mortality. It is important to keep this complex causality in mind when speculating about future trends in human mortality.

It seems reasonable to expect that future mortality trends in the most advanced countries will resemble past changes. Although the focus of efforts to improve health will evolve, the net effect on death rates probably will be similar. Most extrapolations of past trends for the leading industrial countries yield predictions of life expectancy at birth for the sexes combined of around 85 to 87 years by the middle of the twenty-first century. Unexpected events could change the course of these trends. Nevertheless, the historical stability of mortality trends over at least the twentieth century offers strong support for the belief that trends in the twenty-first century will be similar in character.

TABLE 4

Average Change (in Years per Decade) in Key Mortality Indicators, Sweden

Indicator	1861–1960	1970–2000
Average life span (life expectancy at birth)	3.1	1.8
Maximum life span (max. reported age at death)	0.4	1.5
Interquartile range (of deaths in life table)	−5.3	−0.4

Note: The average change shown here equals the difference between mean values for the last and first 10-year periods (within the indicated time interval) divided by the number of years in between.

SOURCE: Author.

See also: *Causes of Death; Demographic Transition; Epidemiological Transition; Health Transition; Life Span; Maternal Mortality; Oldest Old.*

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JOHN R. WILMOTH

MORTALITY DIFFERENTIALS, BY SEX

Sex differences in mortality have varied in different countries, historical periods, and age groups (see Figure 1). During the last quarter of the twentieth century, males had higher mortality than females at all ages in all developed countries and in most less developed countries. However, higher mortality for females was relatively common among young children in less developed countries. During the mid-twentieth century, females also had higher mortality among older children, teenagers, and/or young adults in some less developed countries, particularly in South Asia.

Because males generally had higher mortality than females, males had shorter life expectancies than females in most countries during the period 1950–2000. During the late 1990s, male life expectancy at birth was shorter than female life expectancy by approximately eight years in Europe, six years in North America, seven years in Latin America and the Caribbean, three years in Asia, and two years in Africa. Sex differences in life expectancy varied for different countries within each continent. Probably the largest recorded male disadvantage was in Russia during the late 1990s, when male life expectancy was more than twelve years shorter than female life expectancy. In contrast, males had longer life expectancies than females in some South Asian countries during the mid-twentieth century. For example, in India in the period 1950–1975 male life expectancy was one to two years longer than female life expectancy.

Causes of Death

Major contributors to higher male mortality include coronary heart disease (also known as ischemic heart disease) and injuries, suicide, and homicide (known collectively as external causes of death). For coronary heart disease and for the external causes of